UNITED STATES DEPARTMENT OF AGRICULTURE
Rural Electrification Administration

February 13, 1956

To: Distribution-type Borrowers and System Engineers

Subject: Service to Large Motor Loads

Attached is a copy of an Electric Engineering Division staff report on "Service to Large Motor Loads"

Many questions have come to our attention concerning the problems associated with electrical service to large motors and with various types of phase converters. The solutions to these problems are of immediate concern to the management and operating personnel of a rural electric system.. Specific answers have not been readily available. They have been developed, however, as a result of our staff engineers working with various problems. The attached staff report which was prepared for a recent Technical Conference for REA Field Engineers, embodies some of the answers.

The discussion covers the problems from a primary or distribution voltage viewpoint. Secondary service considerations are treated by national and, where available, local codes. The attached staff report is not a complete coverage of the problems. Our engineers are continuing to work toward a more complete development of a report on the subject.

In the meantime, since service to large motor loads is an important operating and engineering problem, we thought that you would be interested in having a copy of this report. It may be that your experiences and thoughts after reading the report will prompt exploration of your own practices. Any ideas, findings and typical problems that you may submit will enable our engineers to prepare a more useful report on this subject.

R. G. Zook
Assistant Administrator

Attachment

SERVICE TO LARGE MOTOR LOADS

INTRODUCTION

The increased use of electricity in farm operations and the establishment of small industries in rural areas are creating electric service problems not normally associated with domestic use. These problems involve motor loads of all types, both single-phase and three-phase. The starting torques and other load characteristics are of every conceivable magnitude. In fact, the extreme ranges of utilization requirements prohibit formulation of any one set of rules or guides applicable to all.

This paper has been prepared to summarize and present possible solutions to some of the most common problems associated with motor loads.

PHASE CONVERTERS

For many years, practically since the beginning of three-phase power, engineers have attempted to find an inexpensive, reliable method of converting balanced three-phase to single-phase. An equal amount of effort has been expended in the attempt to reverse the process -- to obtain three-phase power from a single-phase source. Either of these conversions is readily accomplished by means of a rotary converter. As these devices are essentially motor-generators, they are expensive and have limited application.

The aim of recent development has been to provide means of operating three-phase motors from single-phase sources. Because of the physical arrangement of the stator windings of a three-phase squirrel cage induction motor, it is possible to operate the motor from a single-phase source. This is accomplished by introducing a phase shift in the supply voltage to one winding of the motor, meanwhile supplying normal single-phase power to the other two motor terminals.

It has been stated that the motor can be induced to operate. Its quality of operation is another matter. If the voltage magnitudes and phase shifts can be made equivalent to those of a three-phase supply, the motor will operate identically with true three-phase power. Under these conditions the conversion is 100% effective as the substitute supply is providing the motor with balanced voltages and currents at all magnitudes of motor loading. Unfortunately, a 100% conversion, as herein qualified, is not obtainable with reasonable cost. For this reason, each type of phase converter offers some compromise in motor operational results.

There are two basic types of static phase converters presently available. One employs a straight capacitor type phase shift; while the other uses a transformer-capacitor combination to obtain the phase shift. A brief review of the overall characteristics of these devices is as follows:

Capacitor Type Phase Converter: This device provides a phase shifted voltage to the motor by placing a capacitance in series with one phase lead of the motor winding. As the effective impedance of the winding at locked rotor is considerably different from that at full speed, different values of capacitance are necessary under the two conditions. This type converter switches a bank of electrolytic capacitors into the circuit during the starting cycle. They

are switched out by a voltage sensitive relay (or a time delay relay) as the motor approaches full speed. This leaves a bank of oil filled capacitors in the series circuit during the running cycle.

The capacitor type converter can be balanced to provide equal voltages and correct phase angles at one running condition -- when the motor power factor is 50% or lower lagging. This operating power factor can be achieved only under a no-load, or very lightly loaded, condition. This does not imply that the motor becomes inoperative when loaded beyond this point. It does mean that motor currents will be unbalanced with reduction in torques normally associated with those magnitudes of currents. The motor will operate without overheating approximately to the point of nameplate current rating. However, the motor will not be producing rated torque. An analysis of the motor circuit could show that two opposing torques are present: (1) A positive torque as a result of the positive sequence (normal) voltages and currents and (2) a negative torque due to the negative sequence (vectors representing the unbalance) voltages and currents. As the normal torque is reduced by a factor representing the degree of unbalance, the horsepower output is likewise reduced.

An installation of a capacitor type converter and three-phase motor must be carefully tailored to the load requirements. After the load horsepower and starting torques have been determined, the converter-connected motor should be selected at least one motor size larger than the nameplate rating would indicate. This derating is not just a cautious move. The motor characteristics have been altered sufficiently to make it a requirement.

Transformer-Capacitor Type Phase Converter: This device employs an autotransformer to raise the nominal single-phase voltage before it is applied through a series capacitor to the third motor lead. This transformer is usually equipped with several taps to permit selection of the suitable voltage to obtain a balanced condition. As in the capacitor type phase converter, this device employs an auxiliary bank of capacitors to provide the correct phase shift for starting. These are removed by a relay during the running cycle. After the motor has reached rated speed and is carrying the load, the motor is checked for balanced voltages and currents. If they are not balanced, the motor is shut down and changes made in the transformer and capacitor taps to obtain better balance. Repeated changes may be required before the motor voltages and currents are within commercial tolerances.

After a motor has been balanced for a particular load, it will remain in balance as long as the supply voltage (single-phase) and load remain constant. Changes in either of these two quantities will affect the supply to the motor. However, small variations in load or voltage input will not seriously unbalance the motor currents. If the motor is operating at rated load or less, the currents will not exceed the nameplate rating.

Caution must also be exercised in applying this type of converter. If starting torque requirements are severe, the motor may have to be selected one size larger than the nameplate rating would indicate.

Special Unit Type Converter: One manufacturer, which also produces a transformer-capacitor type phase converter, has introduced a specially designed motor and capacitor type converter combination. By designing a polyphase induction motor

with unbalanced windings and unusual phase angles between windings, the manufacturer states the motor and phase converter combination will operate as a very efficient, high torque, unit. The motor is not suitable for direct application to either single-phase or three-phase circuits. It must be used in combination with the special phase converter. Properly installed, the combination unit is claimed to provide up to 200% starting and breakdown torques.

The combination of the phase converter and a standard polyphase induction motor changes the full-load slip characteristic drastically. The combination acts as if the motor rotor were of extremely low resistance with correspondingly low slip. To counteract this characteristic, the manufacturer of the special motor and capacitor phase converter combination has incorporated a high resistance rotor in the motor. This provides a slip characteristic comparable to the standard polyphase motor.

The special unit of motor and converter has just been introduced to the market. It is offered in the range from one through 30 horsepower. Care must be used in the application of the larger units as single-phase primary circuits may be taxed to handle the high horsepower requirements.

IRRIGATION MOTORS

The rapid expansion of farm irrigation has brought forth a series of electrical problems peculiar to this application. These difficulties range from failure to obtain coordination of the motor overcurrent protection to the creation of a reversal of phase rotation on part of the distribution system. Not all the difficulties are caused by the pumping installations. Some are the result of other factors indirectly related to the electrical application. The type of primary switching employed, the transformer connections and method of grounding can influence the type of troubles that may appear in an irrigation load area.

Selection and Coordination of Motor Overcurrent Protection: It is universal practice to purchase motor starters with two overcurrent devices. Where primary circuit switching is done on a three-phase basis, this is very satisfactory. However, where primary switching is done with single pole reclosers or fuses, it is possible for a motor to burn out without tripping either of the two overcurrent devices. This can be explained by saying it is caused by a combination of positive and negative sequence currents adding vectorially to produce excessive current in only the unprotected phase of the motor. The best insurance against this type of failure is the installation of an overcurrent element in each phase of the motor. Starters with three overload elements are obtainable from most manufacturers at a slight additional cost over the type having two elements.

The installation of three overcurrent elements in a starter does not solve all the problems associated with these devices. Many of the current sensitive elements are of the thermal type. A consumer may order and install a starter with the correct elements for the motor. However, practically all irrigation pumping installations are made with no shed or housing over the equipment. This means the motor starter is exposed to direct sunlight. As the result of this sunlight exposure, high ambient temperatures and accumulated heat due to load currents, the thermal elements generally derate themselves to a much lower value. This means a motor may trip out even though it is operating at less than full load. When this condition occurs, a consumer is likely to replace the overload elements with others

of higher rating. He has exchanged protection from "too much" to "too little". The motor now has improper overload protection except during the highest ambient temperature interval.

The solution of this problem can be accomplished two ways: (1) Shield the starter from direct sunlight and provide good ventilation about the enclosure. These steps may be all that is necessary to correct the trouble. (2) Change out the thermal overload elements to those of the magnetic type. Magnetic overloads are less sensitive to ambient temperature changes and should retain better calibration. The change-out to magnetic trip elements may require an auxilary enclosure to house the elements. This will complicate the installation and should be used only if the other remedial measures fail.

Phase Reversal on the Distribution System: Occasionally, it is observed that motors run backward as if the phase rotation on the system had been reversed. There is a possibility that this is the case. Omitting phase reversals caused by mechanical switching errors and supply reversals beyond the control of the borrower, it is possible for the irrigation motors, under single-phasing conditions, to establish a phase reversal on the distribution system. It is an established fact, once started, a three-phase induction motor will continue to run and carry some load when energized from a single-phase source. It will generate its own three-phase voltage, supplying the unenergized phase with voltage having normal frequency and phase rotation but slightly reduced in amplitude. If the motor is running in its normal direction, the phase rotation will be normal. To obtain a phase reversal under these conditions, the motors will have to run in the reverse direction. The following case may reveal how this can happen:

Case: A borrower reported that loss of a high-side fuse on a substation (33 kv delta to 7.2 kv 4-wire wye) resulted in severe damage to two irrigation pumps on the system. They were started backward with rupture of couplings and shafts.

Analysis: An analysis of the voltage conditions that exist under the single-phasing conditions outlined above reveals that one phase on the distribution system would have normal voltage while the other two phases would have 1/2 normal voltage (all readings to grounded neutral). These are single-phase voltages with such polarities as to give phase-to-phase voltages of 0.866 normal, 0.866 normal and zero. The voltages on the secondary of a service transformer bank connected floating wye primary, grounded delta secondary would be normal, 1/2 normal, 1/2 normal, all single-phase.

Possible Results: Under these service voltage conditions, approximately 1/3 of the motors on the system would have the starter holding coils on the phase having normal voltage. All other motors would drop off the line as the holding coils would release under the 1/2 voltage condition. As some irrigation pumps are designed so they are not damaged under reverse rotation, motors on these pumps are seldom equipped with anti-reversing devices. The motors, still connected to the system, will not maintain normal horsepower output under the single-phase condition and will probably come to a stop. If the overload devices do not trip out, the motors will be started backward by the torque exerted on the impeller by the water running back down the well casing. Once started, the motors are practically

unloaded and will continue to run. If this happens, the initial voltage conditions are destroyed and the system has three-phase voltage, reverse phase rotation, with the motor energized phase voltage slightly lower than normal. Anyone attempting to restart a pump which had dropped off the system under the initial voltage conditions would find the pump starting backward under practically normal starting torque. If pumps are not designed for reverse rotation, this can result in severe damage such as dropping the impeller and shaft by unscrewing a coupling or rupturing couplings or shafts.

The above analysis is only one possibility of the cause of the trouble. However, the damage to some pumping installations is so great under reverse starting that mention should be made of devices that will prevent this from happening.

Anti-Reversing Ratchets: This is a mechanical ratchet that is incorporated in the motor drive assembly to lock the motor shaft to the frame if the motor is started backward or if the returning water attempts to drive the motor backward. Under reverse starting, the overcurrent devices would remove the motor from the circuit to prevent damage. This device is illustrated in figure 1.

Motor Release Coupling: This is also a mechanical device, figure 2, that releases the motor from the pump if the motor is started in reverse direction. As the direction of applied torque is the same for the returning water in the casing as it is for the normal drive of the motor, this device will not prevent the motor from spinning during the normal rundown of water in the well. Of more importance, this device will not prevent the motor from being started and run backward. It will merely prevent the motor from driving the pump backward. Motor release couplings are of no value in the phase reversal analysis used above. The motor will be rotated backward by the pump impeller, when it reaches sufficient speed to reverse the direction of torque, the coupling will separate and permit the motor to continue running with the pump disconnected.

Phase Reversal Relay: This device, figure 3, is an electrical relay that holds contacts closed as long as the phase rotation is normal. It will also open the contact under single-phasing conditions. As the control contacts are placed in series with the motor starter holding coil, the motor will be deenergized under either single-phasing of reverse phase rotation conditions. This device will prevent reverse phase rotation being established on the system by the motors and will also prevent reverse starting damage.

Stoppage of Motors on Temporary System Faults: One of the major complaints by irrigation users is centered around the water distribution system employed on the farm. Distribution of water to individual rows or multiple rows is sometimes accomplished by using syphons to transfer water from a main distribution canal to the laterals. If the irrigation pump stops for more than a few minutes, the water level in the main canal is lowered to such an extent that all syphons are broken. This means the pump and all syphons must be restarted after each oil circuit recloser operation that affects the starter holding coil. With good justification, the farmer considers this a lot of unnecessary work. He wants a device, some type of delay relay, that will hold the starter in the run position (or return it to the run position) during a portion of the coast down time of the motor. As this device must obtain its timing

when electrical energy is not present, it must have some means of storing energy to drive the timing element when the circuit is deenergized.

One solution to the problem is to by-pass the START contacts with a relay that keeps the starter in the run setting for a predetermined period of time after the circuit interruption. These time delay relays are available in spring return escapement, pneumatic spring loaded return, and thermal type. They should be purchased with adequate time range to suit local conditions. One special device for this purpose is shown in figure 4. Its function is accomplished by placing the holding coil under direct current control with capacitors supplying the energy for 4 to 8 seconds after circuit interruption. The timing can be changed by substitution of other values of capacitance.

MOTOR STARTING METHODS

Single-Phase Motors: REA has no requirements or limitations on horsepower sizes for single-phase motors. In the early days, it was suggested that single-phase motors be limited to five horsepower. Since the rural circuits in those days were low capacity and quite long, this suggestion was valid. In recent years, the circuits have been shortened and increased in capacity. It is now suggested that each borrower serve motors as large as the circuits will permit, consistent with voltage flicker characteristics of the load. If single-phase motors can be operated with across-the-line starting without serious voltage flicker, they should be permitted. If across-the-line starting is permitted, provisions should be made in the service contract with the consumer to require reduced voltage starting, when and if it becomes necessary.

Single-phase motors are now available in ratings as high as 15 horsepower. Some manufacturers are experimenting with 20 horsepower models which may be on the market in the near future. In general, these larger motors are capacitor-start, capacitor-run with good operating characteristics. They are not particularly suited to reduced voltage starting. However, they can be started by this method if the starting torques of the loads will permit it. As previously stated, one manufacturer of phase converters is now offering a combination of specially designed motor and converter in sizes from one through 30 horsepower. This device should be treated as a single-phase motor, with the locked rotor current obtained from the characteristics of the combination of converter and motor. Reduced voltage starting should not be applied to this device unless specifically recommended by the manufacturer.

Polyphase Motors: Three-phase motors should be applied in the same manner as single-phase motors. They should be served with across-the-line starting where possible. However, the power supplier should protect itself against poor operating practices and changes in circuit characteristics by specifying that reduced voltage starting must be installed if and when required. This will keep the consumer's investment to a minimum, comensurate with good service to all concerned.

Special Starting Devices: Recently, considerable interest has been created in special starting clutches for motor drives. Among these are trade names such as "BLM," "Electrofluid," "E-M Magnetic Drive," "Flexidyne," "Gyrol." They all operate on the principle of allowing the driving motor to reach a high percentage of full speed before the load is picked up. The manner in which the drive is transmitted varies with each type of clutch. Some are electromagnetic, hydraulic, pneumatic, friction shoes or friction pellets.

Drives in this category do not reduce locked rotor inrush current magnitude. The same initial inrush (starting) current magnitude will be measured on a drive equipped motor as would be present on an across-the-line start using conventional pulley and belt drive. However, the duration of the inrush current is reduced as the drive unit allows the motor to gradually bring the load up to speed. The time required for the locked rotor current to fall back to full load value will be determined by the characteristic of the load and the adjustment of the drive unit.

Human reaction to voltage flicker is a variable and is influenced by many factors such as frequency, amplitude, duration and time of day. There are probably many motor installations where the clutch drive units will prove satisfactory as a substitute for a reduced voltage starter. The power supplier should determine whether or not these drives are equivalent to the reduced voltage starters for certain type loads. If the drive unit is applicable, the power supplier should not specify that such drives be used; but, should make them an alternate to the starter.

The clutch drives are designed to aid motor users in several ways other than elimination of reduced voltage starters. Some of these are:

1. They can reduce shock loading on machine drives, thus reducing maintenance.

2. They can permit motors to break away on overloads, reducing motor burnouts and circuit interruptions.

3. They may permit starting high inertia loads with smaller motors, saving the user considerable in equipment costs.

4. They may eliminate the need for speed reducers (for starting).

It must be kept in mind that clutch drives are consumer equipment, similar to motors, speed reducers, starters and drive assemblies. These installations should be served where such services do not deteriorate the quality of service to other consumers.

FLICKER VOLTAGE*

Consumer Reaction: The calculations for voltage drop caused by motor starting currents are relatively simple. After these have been made and the magnitude of the flicker voltage is known, it has to be determined if the magnitude is sufficient to cause consumer irritation. Some estimates indicate that infrequent primary line voltage flicker could be as great as six volts (referred to a 120 volt base) and not result in a complaint. Infrequent flicker would include cases occurring six times or less in twenty-four hours, but not more than once between 6:00 p.m. and midnight. Where there is high motor saturation, such as an irrigation area, the magnitude of voltage flicker should be kept to a minimum for any one load, probably about three volts. Local experience is the best guide as to permissible levels.

The television receiver is one of the most sensitive flicker voltage indicators. The picture response is far more sensitive to sudden voltage changes than the best indicating voltmeters. If the distribution area has a reasonable saturation of tele-

*This material was developed by Roland W. Schlie, Electric Engineering Division, REA

vision receivers, voltage flicker complaints are likely to be far more severe than in a similar area with no television.

In general, if calculations do not reveal voltage flicker levels beyond previous complaint-free installations, it should be safe to permit the load to be connected. If calculations show more severe flicker, caution should be used in supplying power to the applicant under the proposed starting conditions.

Flicker calculations: The general equation for the calculation of voltage drop is as follows:

$$\text{Voltage Drop} = I\,S\,(R \cos\theta + X \sin\theta) \qquad (1)$$

Where: Voltage Drop is expressed in volts

I = amperes per phase
S = line distance in miles
R = resistance of line in ohms per mile
X = reactance of line in ohms per mile
θ = angle between load voltage and current (Power Factor angle)

The power factor angles of motor starting currents are relatively low and vary considerably for the different types and sizes of motors. Normal starting power factors for induction motors up to 150 horsepower are shown in figure 5.

To simplify the equations, three nominal values of starting power factor, 0.30, 0.45 and 0.60 have been used to calculate the values of ($R \cos\theta + X \sin\theta$). If these values are designated as K, the wire constant, then the formula for any wire size and number of phases becomes:

$$\text{Voltage Drop} = I\,S\,K \qquad (2)$$

The following table illustrates the various values for K, the wire constant, for various configurations and wire sizes with spacings used on 7,200 volt and 14,400 volt circuits:

TABLE I

WIRE CONSTANT, K

Wire Size Cu. Equiv.	V-Phase & Single-phase			Three-phase		
Power Factor	0.30	0.45	0.60	0.30	0.45	0.60
8	2.5	3.0	3.5	1.9	2.4	2.8
6	2.0	2.4	2.6	1.4	1.7	2.0
4	1.7	1.9	2.1	1.2	1.3	1.5
2	1.4	1.6	1.6	1.0	1.1	1.2
1	1.3	1.4	1.4	0.91	0.98	1.0
1/0	1.2	1.2	1.2	0.86	0.90	0.92
2/0				0.80	0.83	0.83
3/0				0.72	0.74	0.73
4/0				0.68	0.69	0.67

The locked rotor current of a three-phase induction motor is between 580% and 600% of the rated full-load current of the motor. However, if the secondary circuit to the motor is correctly designed for up to 3% regulation at full load, the motor will not have rated voltage on its terminals under the locked rotor condition. If it is not supplied with rated voltage, it will not draw full rated locked rotor current. In other words, because of drop in supply voltage, there will be a drop in the starting currents.

To simplify equations and to approximate the conditions of locked rotor values, we can assume the following:

1. Primary rated current, full-load, of the motor is approximately equal to one-third the horsepower rating of the motor divided by the line-to-ground voltage in kilovolts: $I_{FL} = \frac{\text{Horsepower}}{3 \times 7.2}$

2. Locked rotor current of the motor will be 500% of the full-load current:

$$I_{LR} = \frac{5 \times \text{Horsepower}}{3 \times 7.2} = 0.23 \times \text{Horsepower} \qquad (3)$$

On V-Phase circuits, the phase current due to a three-phase motor load is the same magnitude as for full three-phase circuits. However, because of phase angles between the secondary currents and the primary currents, the neutral on a V-Phase circuit will have 1.73 times the phase current for balanced three-phase secondary loads. Thus, we have the following for V-Phase circuits:

$$\text{Phase } I_{LR} = 0.23 \times \text{Horsepower}$$

$$\text{Neutral } I_{LR} = 1.73 \times 0.23 \times \text{Horsepower} = 0.40 \times \text{Horsepower}$$

Voltage drop on the V-Phase circuit is approximately equal to the circuit constants multiplied by the average current. Therefore:

$$\text{V-Phase Current, } I_{LR} = \frac{(0.40 + 0.23) \times \text{Horsepower}}{2}$$

$$I_{LR} = 0.31 \times \text{Horsepower} \qquad (4)$$

On a single-phase circuit the phase (and neutral) current is approximately equal to the horsepower of the single-phase motor divided by the line voltage in kilovolts. Thus, we have:

$$I_{FL} = \frac{\text{Horsepower}}{7.2} = 0.14 \times \text{Horsepower}$$

Likewise: $I_{LR} = \frac{5 \times \text{Horsepower}}{7.2} = 0.69 \times \text{Horsepower}$ (5)

The simplified equations for voltage drop for locked rotor currents, equation (2), now become:

Three-Phase Circuits:

$$\text{Voltage Drop} = 0.23 \times HP \times S \times K \qquad (6)$$

V-Phase Circuits:

$$\text{Voltage Drop} = 0.31 \times HP \times S \times K \qquad (7)$$

Single-Phase Circuits:

$$\text{Voltage Drop} = 0.69 \times HP \times S \times K \qquad (8)$$

As the above equations are actually flicker voltages at the primary voltage level, we wish to refer the values to the nominal 120 volt base. This is accomplished by dividing the above quantities by 60, the transformation ratio for 7,200 volts to 120 volts. The equations then become:

Three-Phase: $\text{Voltage Drop} = 0.0038 \times HP \times S \times K \qquad (9)$

V-Phase: $\text{Voltage Drop} = 0.0052 \times HP \times S \times K \qquad (10)$

Single-Phase: $\text{Voltage Drop} = 0.0115 \times HP \times S \times K \qquad (11)$

If equations (9), (10) and (11) are applied to the various wire sizes, the result will be voltage drop, on a 120 volt base, per horsepower-mile. These values are shown in table II.

TABLE II

FLICKER VOLTAGE ON A 120 VOLT BASE
(MOTOR STARTING VALUES)

Wire Size Cu. Equiv.	Volts Drop Per Horsepower Mile								
	Single-Phase			V-Phase			Three-Phase		
PF	0.30	0.45	0.60	0.30	0.45	0.60	0.30	0.45	0.60
8	0.029	0.034	0.040	0.013	0.016	0.018	0.0072	0.0091	0.0106
6	0.023	0.028	0.030	0.010	0.012	0.014	0.0053	0.0065	0.0076
4	0.020	0.022	0.024	0.0088	0.0099	0.011	0.0046	0.0049	0.0057
2	0.016	0.018	0.018	0.0073	0.0083	0.0083	0.0038	0.0042	0.0046
1	0.015	0.016	0.016	0.0068	0.0073	0.0073	0.0034	0.0037	0.0038
1/0	0.014	0.014	0.014	0.0062	0.0062	0.0062	0.0033	0.0034	0.0035
2/0							0.0030	0.0032	0.0032
3/0							0.0027	0.0028	0.0028
4/0							0.0026	0.0026	0.0025

SAMPLE CALCULATIONS

The sample problem in figure 6 will illustrate the use of tables in determining flicker voltages from motor starting currents. As indicated in figure 6, there are five motor loads on one feeder, scheduled for across-the-line starting. In tabular form, the flicker voltage drops are shown below:

FLICKER VOLTAGE DROP CALCULATION

Motor Installation	Horsepower Miles	Circuit Used	Voltage Drop Constant (Table II)	Voltage Drop on 120 volt base Section	Total
B-50 HP 3Ø	500	#2-3Ø	0.0042	2.1	2.1
B-20 HP 1Ø	200	#2-1Ø	0.0180	3.6	3.6
C-30 HP VØ	300	#2-VØ	0.0083	2.5	
	150	#4-VØ	0.0099	1.5	4.0
D-25 HP VØ	250	#2-VØ	0.0083	2.1	
	125	#4-VØ	0.0099	1.2	
	200	#6-VØ	0.0120	2.4	5.7
E-15 HP 1Ø	150	#2-1Ø	0.0180	2.7	
	75	#4-1Ø	0.0220	1.6	
	120	#6-1Ø	0.0280	3.4	
	150	#8-1Ø	0.0340	5.1	12.8

NOTE: Voltage drop under running conditions will be slightly less than 20% of the values obtained for across-the-line starting.

Fig. 1. Anti-reversal Ratchet

Fig. 2. Motor Release Coupling

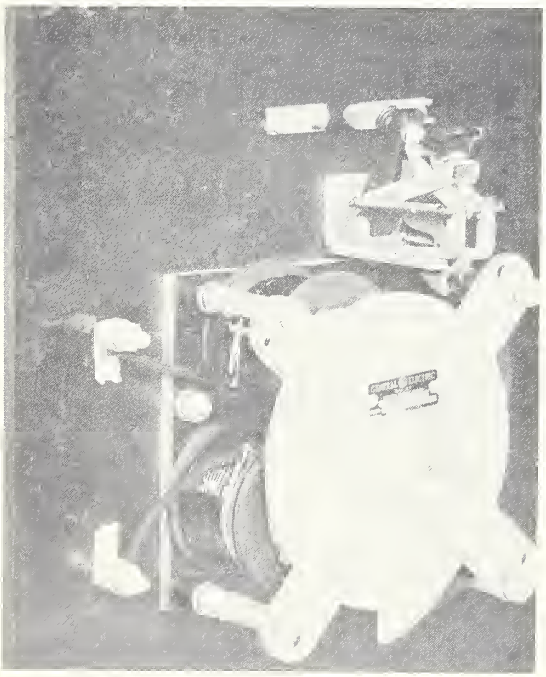

Fig. 3. Phase-reversal Relay

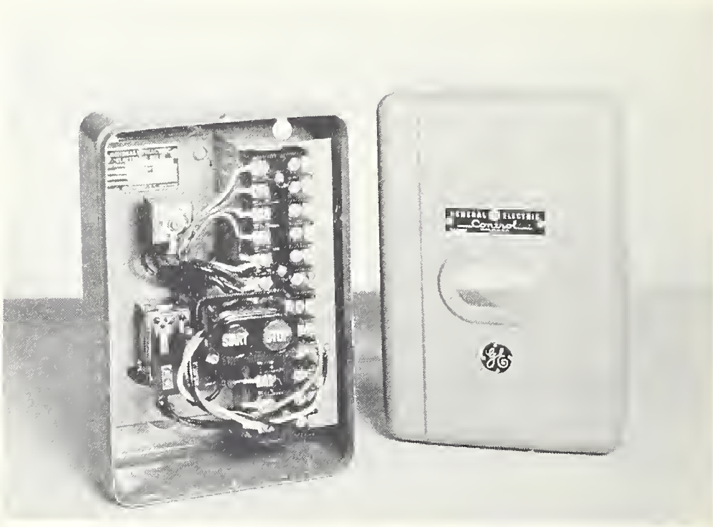

Fig. 4. Time Delay Station

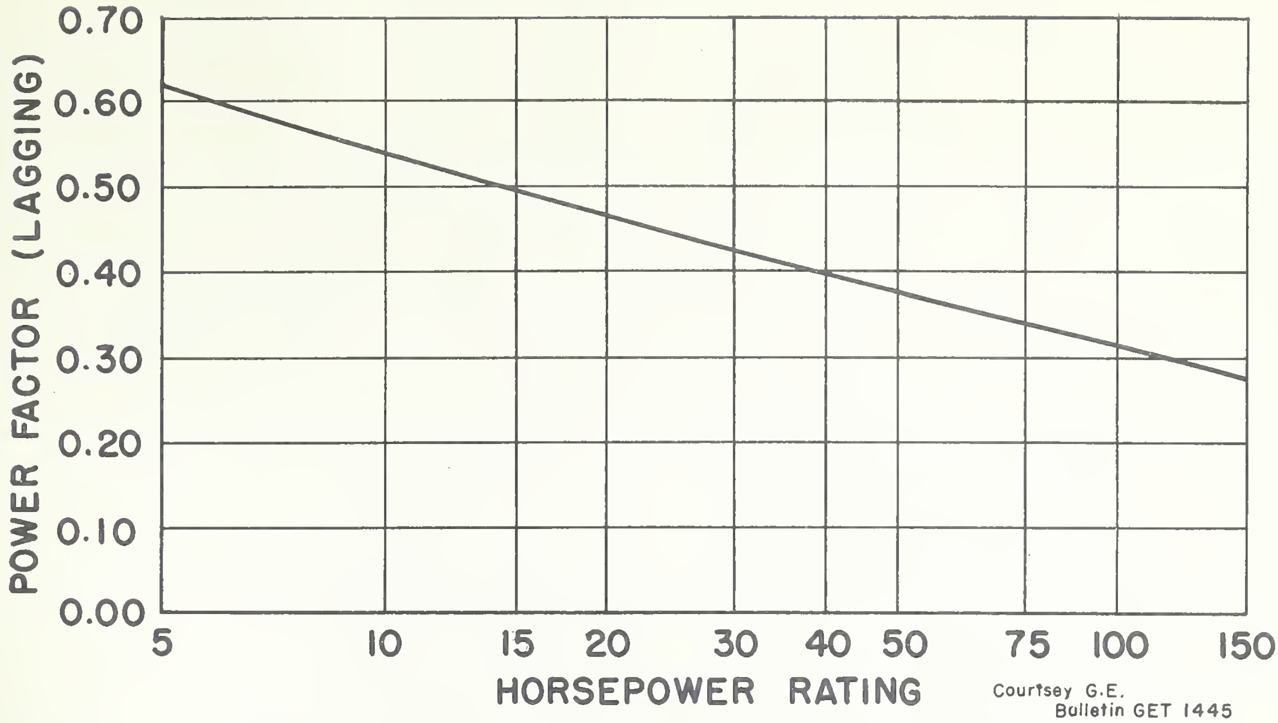

Fig. 5. Motor Starting Power Factors

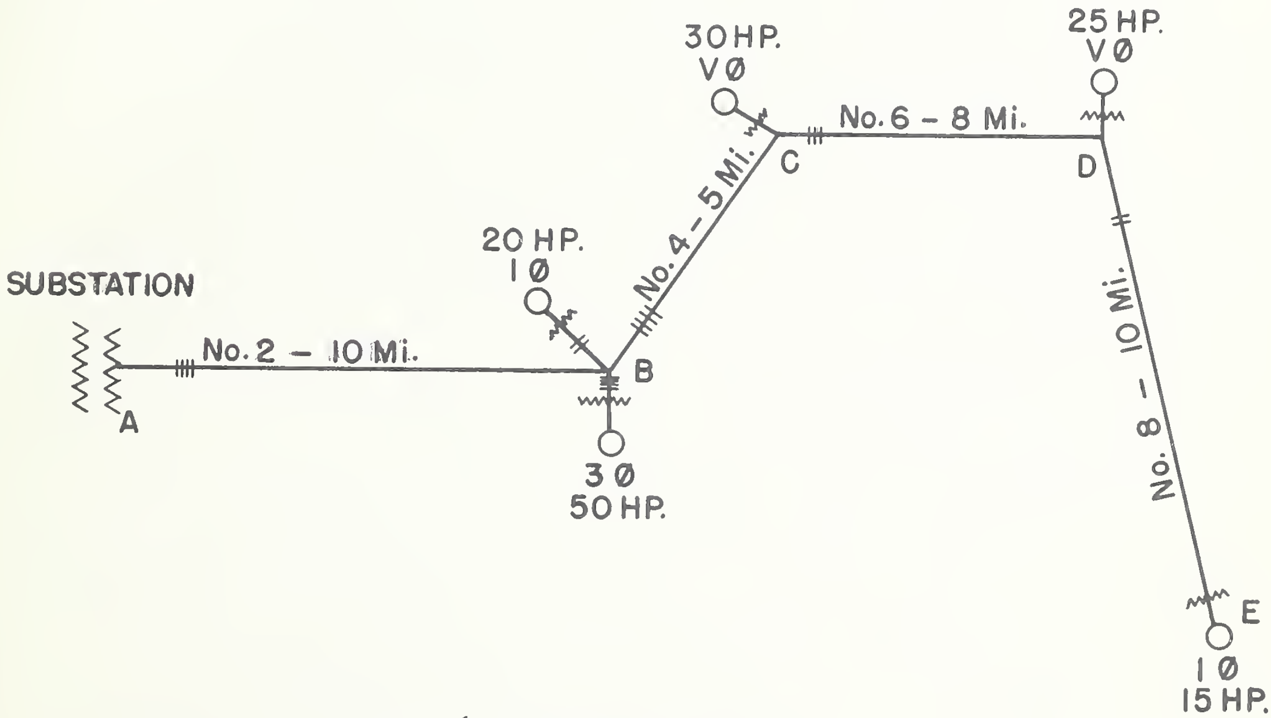

Fig. 6. Sample Problem